



FINAL SUBMITTAL

EXECUTIVE SUMMARY

ENERGY SURVEY OF ARMY BOILER AND CHILLER PLANTS FT. SILL, OKLAHOMA

Prepared for

TULSA DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA

19971023 152

Under

CONTRACT NO. DACA 56-90-C-0087

EMC QUALITY INSPECTION



E M C ENGINEERS, INC.
Denver, Colorado
Colorado Springs, Colorado
Atlanta, Georgia

DISTRIBUTION STATEMENT A

Approved for public release,
Distribution Unlimited




DEPARTMENT OF THE ARMY
CONSTRUCTION ENGINEERING RESEARCH LABORATORIES, CORPS OF ENGINEERS
P.O. BOX 9005
CHAMPAIGN, ILLINOIS 61826-9005

REPLY TO
ATTENTION OF: TR-I Library

17 Sep 1997

Based on SOW, these Energy Studies are unclassified/unlimited.
Distribution A. Approved for public release.


Marie Wakefield,
Librarian Engineering

FINAL SUBMITTAL

EXECUTIVE SUMMARY

ENERGY SURVEY OF ARMY BOILER AND CHILLER PLANTS FT. SILL, OKLAHOMA

Prepared for

**TULSA DISTRICT
CORPS OF ENGINEERS
TULSA, OKLAHOMA**

Under

CONTRACT NO. DACA 56-90-C-0087

April 1992

EMC No. 3002.000

E M C ENGINEERS, INC.
1950 Spectrum Circle
Suite B-312
Marietta, Georgia 30067
Phone (404) 952-3697

EXECUTIVE SUMMARY

PURPOSE OF STUDY

This study was conducted and this submittal prepared under Contract DACA56-90-C-0087. The contract was issued by the Corps of Engineers, Tulsa District, as of 21 August 1990. This submittal presents the results of a study analyzing energy requirements and energy conservation opportunities (ECOs) for Army boiler and chiller plants at Fort Sill, Oklahoma.

SUMMARY OF FIELD SURVEY FINDINGS

A field survey was completed in which the nine central plants were tested to determine the efficiency, condition, and operation of the plants. Overall, 18% of all boilers had problems and 68% of all chillers had problems. Of the 28 boilers and 19 chillers surveyed and tested, the following conditions were noted:

- Central Plant 730: chiller 4 was not operational; boiler 1 has a problem with soot, which indicates incomplete combustion.
- Central Plant 914: the new chiller would develop only 33% of rated capacity without surging; the automated control system was not functional. The poor design of the common breaching on the four boilers causes soot on boilers 3 and 4.
- Central Plant 2812: no special problems were noted.
- Central Plant 3442: heavy deposits were noted on the cooling tower; the central plant has an automated control system which was not being used.
- Central Plant 4701: chillers are in need of major repair or replacement; the high pressure steam boilers are old but seem to be in good operating condition.
- Central Plant 5676: the chiller had a high pressure drop across the evaporator; the two hot water boilers may require major repair or replacement.
- Central Plant 5678: the chiller surged with a heavy cooling load.
- Central Plant 5900: the only major concern is the cooling tower on chiller 1, which will not provide adequate heat rejection for the chiller.
- Central Plant 6003: chiller 1 was not operational; chillers 2 and 3 surged.

CHILLERS AND BOILERS DATA

Table ES-1 on pages ES-3 and ES-4 lists chillers and boilers surveyed and their sizes, along with the tested chiller efficiencies, tested boiler efficiencies, and the tested boiler percent excess air. Chiller efficiencies ranged from 0.61 kW per ton to 1.53 kW per ton. Boiler efficiencies ranged from 67% to 82%. Chiller efficiency ranges from 0.6 to 0.8 kW per ton are considered satisfactory. Boiler efficiency ranges from 77% to 82% are considered satisfactory.

TABLE ES-1
MAJOR CENTRAL PLANT EQUIPMENT

CENTRAL PLANT	BOILER NO.	BOILER SERVICE	BOILER EFF.	BOILER MFG	BOILER (MMBtu/h)	CHILLER NO.	TESTED (kW/ton)	CHILLER MFG	CHILLER (Tons)
730	1	STEAM	NA	KEWANEE	7.75	1	0.89	TRANE	800
	2	STEAM	81.4%	KEWANEE	7.75	3	0.74	TRANE	320
	3	STEAM	81.7%	KEWANEE	7.75	4	N/A	TRANE	320
	4	STEAM	81.5%	KEWANEE	2.66				
914	1	STEAM	82.0%	BRUNHAM	1.61	1	1.07	TRANE	400
	2	HW	77.4%	RAY-PAK	1.61				
	3	HW	77.9%	AMERICAN STANDARD	1.92				
	4	HW	74.4%	AMERICAN STANDARD	1.92				
2812	1	STEAM	79.7%	FEDERAL BOILER CO	1.80	1	0.81	CARRIER	170
	2	HW	71.5%	THERMO-PAK	3.95				
	3	HW	74.0%	THERMO-PAK	3.95				
3442	NONE					1	0.68	TRANE	600
	NONE					2	0.62	TRANE	600
4701	1	STEAM	79.2%	BIRCHFIELD	11.00	1	1.14	CARRIER	305
	2	STEAM	NA	BIRCHFIELD	11.00	2	0.97	CARRIER	305
	3	STEAM	79.2%	BIRCHFIELD	11.00				

N/A - Not available because of equipment problems.

TABLE ES-1
MAJOR CENTRAL PLANT EQUIPMENT (Concluded)

CENTRAL PLANT	BOILER NO.	BOILER SERVICE	BOILER EFF.	BOILER MFG	BOILER (MMBtu/h)	CHILLER NO.	TESTED (kW/Ton)	CHILLER MFG	CHILLER (Tons)
5676	1	HW	75.1%	AMERICAN STANDARD	2.44	1	1.47	CARRIER	170
	2	HW	71.4%	AMERICAN STANDARD	2.44				
5678	1	HW	67.5%	BRUNHAM	2.27	1	0.71	TRANE	190
	2	HW	73.3%	BRUNHAM	2.27				
5900	1	HTHW	70.9%	INTERNATIONAL	10.00	1	0.92	CARRIER	400
	2	HTHW	73.2%	INTERNATIONAL	10.00	2	0.94	WESTINGHOUSE	400
	3	HTHW	80.8%	HERCULES	9.70	3	0.85	CARRIER	400
	4	HTHW	79.6%	HERCULES	9.70	4	0.94	MCQUAY	450
	5	HTHW	79.2%	INTERNATIONAL	8.00	5	0.85	CARRIER	400
	6	HTHW	80.8%	INTERNATIONAL	11.20				
6003	1	STEAM	82.3%	KEWANEE	11.72	1	NA	TRANE	400
	2	STEAM	79.8%	YORK SHIPLEY	11.72	2	NA	TRANE	450
	3	STEAM	NA	KEWANEE	11.72	3	NA	TRANE	450

N/A - Not available because of equipment problems.

ENERGY CONSERVATION OPPORTUNITY (ECO) ANALYSIS

The following method was used to perform the economic analysis for the central plants:

- Determine the current annual energy consumption as the baseline for evaluating ECOs on a plant-by-plant basis.
- Estimate the utility and maintenance usage for technically viable ECOs.
- Calculate the utility and maintenance savings or costs for an ECO by comparing the usage with the baseline estimate.
- Prepare a cost estimate for the ECO modification.
- Perform a life cycle cost analysis of the ECO.

Table ES-2 on page ES-6 lists the ECOs evaluated. Each individual ECO was evaluated as a stand-alone project. Interrelationships between individual ECOs were not taken into consideration. All of the individual ECOs determined to be technically feasible were evaluated for utility savings. The technically feasible individual ECOs are listed, by central plant, on Table ES-3, starting on page ES-7. The table provides the predicted annual energy savings (type and amount), annual dollar savings, construction costs, and life cycle economics, including savings-to-investment ratio (SIR) and simple payback.

Table ES-4 on page ES-12 lists individual ECOs evaluated by central plant. Table ES-5, beginning on page ES-13, lists the individual ECOs rejected because they were not technically feasible or were not applicable because of the condition of the plant.

A total of 81 individual ECOs were determined to be technically feasible; these were evaluated for potential utility savings. Of the individual ECOs evaluated, 26 projects had an SIR greater than 1.0 (see Table ES-3 on page ES-7). Those ECOs having an SIR of 1.0 and greater are by definition economically feasible. The total estimated construction cost for the 26 projects is \$1,127,328.

**TABLE ES-2
ECO LIST**

ECO NUMBER	ECO DESCRIPTION	SPECIAL PROJECT - CENTRAL PLANT NUMBER
1.	Install instrumentation to establish chiller plant load to improve the plant operations, thereby saving energy.	
2.	Control systems to match chiller capacity and characteristics with the load, thereby saving energy.	
3.	Renovate or replace chillers to improve chiller efficiency, thereby saving energy.	
4.	Install ice storage cooling system to reduce peak air conditioning electrical demand.	
5.	5(A) - Install two-speed cooling tower fans to reduce cooling tower electrical energy. 5(B) - Install variable-speed cooling tower fans to reduce cooling tower electrical energy.	
6.	Install high efficiency motors to save electrical energy.	
7.	Install instrumentation to establish boiler plant load to improve the plant operations, thereby saving energy.	
8.	Control systems to match boiler capacity and characteristics with the load, thereby saving energy.	
9.	Renovate or replace boilers to improve efficiency, thereby saving energy.	
10.	Install combustion controls to assure proper fuel-to-air ratio; increase combustion efficiency, thereby saving energy.	
11.	Install new high efficiency burners on boilers to increase combustion efficiency, thereby saving energy.	
12.	Install stack economizer or air preheater to recover heat from the boiler stack, thereby saving energy.	
13.	Install chilled water variable speed pumping to improve flow and pressure drop in the distribution system, saving electrical energy.	5900
14.	Install smaller pumps to match flow requirements, saving electrical energy.	730 & 4701
15.	Install a cogeneration, natural gas turbine engine, to generate electricity on-site, saving electrical demand and energy.	6003
16.	Install natural gas driven chillers to save electrical demand and energy.	2812
17.	Install electric boilers in buildings for summer DHW to shut down central plant in the summer, saving distribution loss and pumping energy.	730 & 2812

TABLE ES-3
ECONOMIC SUMMARY OF ECOs LISTED BY CENTRAL PLANT

CENTRAL PLANT	ECO NO.	ANNUAL DEMAND SAVINGS (kW)	ANNUAL ELEC. SAVINGS (kWh)	ANNUAL NAT.GAS SAVINGS (MMBtu)	TOTAL ENERGY SAVINGS (MMBtu)	ANNUAL ENERGY SAVINGS (\$)	ANNUAL DEMAND CREDIT (\$)	ANNUAL MAINT. COST (\$)	CONST. COST (\$)	SIR	SIMPLE PAYBACK (YRS)
730	1	129	243,000	0	829	\$3,329	\$2,766	\$320	\$5,620	9.6	0.9
	2	163	338,000	0	1,154	\$4,631	\$3,495	\$1,077	\$18,939	3.5	2.6
	3	22	2,000	0	7	\$27	\$472	\$3,000	\$6,330	-3.8	N/A
	4	712	0	0	0	\$0	\$15,268	\$0	\$192,000	0.9	12.6
	5(A)	0	17,441	0	60	\$239	\$0	\$0	\$14,890	0.2	59.3
	5(B)	0	18,709	0	64	\$256	\$0	\$579	\$10,180	-0.4	N/A
	6	41	85,430	0	292	\$1,170	\$879	\$0	\$50,297	0.5	23.3
	7	0	0	89	89	\$260	\$0	\$255	\$4,482	0.2	966.1
	10	0	0	108	108	\$315	\$0	\$2,411	\$29,654	-0.6	N/A
	14	0	144,560	0	493	\$1,980	\$0	\$0	\$12,809	1.9	6.2
	17	(121)	(48,800)	1,582	1,415	\$3,951	(\$2,595)	\$0	\$38,431	1.2	27.0
914	3	93	130,000	0	444	\$1,781	\$1,994	\$3,000	\$3,165	2.2	3.9
	4	428	0	0	0	\$0	\$9,178	\$0	\$96,000	1.1	10.5
	5(B)	0	2,697	0	9	\$37	\$0	\$361	\$6,352	-0.6	N/A
	6	5	8,932	0	30	\$122	\$107	\$0	\$9,429	0.3	39.1
	7	0	0	11	11	\$32	\$0	\$320	\$5,620	-0.5	N/A

TABLE ES-3
ECONOMIC SUMMARY OF ECOs LISTED BY CENTRAL PLANT

CENTRAL PLANT	ECO NO.	ANNUAL DEMAND SAVINGS (kW)	ANNUAL ELEC. SAVINGS (kWh)	ANNUAL NAT.GAS SAVINGS (MMBtu)	TOTAL ENERGY SAVINGS (MMBtu)	ANNUAL ENERGY SAVINGS (\$)	ANNUAL DEMAND CREDIT (\$)	ANNUAL MAINT. COST (\$)	CONST. COST (\$)	SIR	SIMPLE PAYBACK (YRS)
914	8	0	0	44	44	\$128	\$0	\$2,031	\$33,847	-0.5	N/A
(Continued)	9	0	0	500	500	\$1,460	\$0	\$3,000	\$18,035	-0.5	N/A
2812	3	42	72,000	0	246	\$986	\$901	\$3,000	\$94,894	-0.2	N/A
	4	301	0	0	0	\$0	\$6,455	\$0	\$89,280	0.8	13.8
	5(A)	0	8,560	0	29	\$117	\$0	\$0	\$7,077	0.2	57.4
	5(B)	0	11,167	0	38	\$153	\$0	\$298	\$5,236	-0.4	N/A
	6	4	18,353	0	63	\$251	\$86	\$0	\$8,368	0.5	23.6
	7	0	0	21	21	\$61	\$0	\$320	\$5,620	-0.4	N/A
	8	0	0	307	307	\$896	\$0	\$1,543	\$27,128	-0.1	N/A
	9	0	0	621	621	\$1,813	\$0	\$1,056	\$6,012	2.2	8.0
	16	144	278,000	(1,498)	(549)	(\$566)	\$3,088	\$384	\$444,584	0.0	185.0
	17	(176)	(726,000)	7,346	4,868	\$11,504	(\$3,774)	\$0	\$181,078	1.3	22.3
3442	1	0	209,000	0	713	\$2,863	\$0	\$228	\$4,012	6.0	1.5
	2	0	281,000	0	959	\$3,850	\$0	\$936	\$16,449	1.6	5.4
	4	780	0	0	0	\$0	\$16,726	\$0	\$288,000	0.7	17.2
	5(B)	0	35,884	0	122	\$492	\$0	\$597	\$10,499	-0.1	N/A
	6	4	12,880	0	44	\$176	\$86	\$0	\$25,318	0.1	92.1

TABLE ES-3
ECONOMIC SUMMARY OF ECOs LISTED BY CENTRAL PLANT

CENTRAL PLANT	ECO NO.	ANNUAL DEMAND SAVINGS (kW)	ANNUAL ELEC. SAVINGS (kWh)	ANNUAL NAT.GAS SAVINGS (MMBtu)	TOTAL ENERGY SAVINGS (MMBtu)	ANNUAL ENERGY SAVINGS (\$)	ANNUAL DEMAND CREDIT (\$)	ANNUAL MAINT. COST (\$)	CONST. COST (\$)	SIR	SIMPLE PAYBACK (YRS)
4701	1	0	71,000	0	242	\$973	\$0	\$320	\$5,620	3.1	2.9
	2	0	178,000	0	608	\$2,439	\$0	\$234	\$16,929	1.2	7.3
	3	113	126,000	0	430	\$1,726	\$2,423	\$3,000	\$218,314	0.1	180.7
	4	583	0	0	0	\$0	\$12,502	\$0	\$132,000	1.1	10.6
	5(B)	0	17,453	0	60	\$239	\$0	\$1,013	\$17,808	-0.5	N/A
	6	3	4,605	0	16	\$63	\$64	\$0	\$18,176	0.1	136.1
	7	0	0	61	61	\$178	\$0	\$463	\$8,145	-0.3	N/A
	10	0	0	160	160	\$467	\$0	\$1,799	\$24,869	-0.5	N/A
	12	0	0	89	89	\$260	\$0	\$0	\$46,799	0.1	198.0
	14	0	50,401	0	172	\$690	\$0	\$0	\$21,168	0.4	29.2
5676	3	96	137,000	0	468	\$1,877	\$2,059	\$3,000	\$94,320	0.1	95.9
	4	250	0	0	0	\$0	\$5,361	\$0	\$40,800	1.5	7.6
	5(A)	0	4,100	0	14	\$56	\$0	\$0	\$4,296	0.2	72.8
	5(B)	0	4,970	0	17	\$68	\$0	\$289	\$5,076	-0.5	N/A
	6	4	24,287	0	83	\$333	\$86	\$0	\$4,797	1.1	10.9
	7	0	0	13	13	\$38	\$0	\$0	\$5,620	-0.5	N/A
	9	0	0	5,520	5,520	\$16,118	\$0	\$0	\$105,344	1.6	11.8

TABLE ES-3
ECONOMIC SUMMARY OF ECOs LISTED BY CENTRAL PLANT

CENTRAL PLANT	ECO NO.	ANNUAL DEMAND SAVINGS (kW)	ANNUAL ELEC. SAVINGS (kWh)	ANNUAL NAT.GAS SAVINGS (MMBtu)	TOTAL ENERGY SAVINGS (MMBtu)	ANNUAL ENERGY SAVINGS (\$)	ANNUAL DEMAND CREDIT (\$)	ANNUAL MAINT. COST (\$)	CONST. COST (\$)	SIR	SIMPLE PAYBACK (YRS)
5676	10	0	0	238	238	\$695	\$0	\$1,799	\$24,869	0.3	21.4
(continued)	12	0	0	718	718	\$2,097	\$0	\$0	\$31,635	1.3	14.0
5678	4	142	0	0	0	\$0	\$3,045	\$0	\$48,000	0.7	15.8
	5(A)	0	3,873	0	13	\$53	\$0	\$0	\$4,296	0.2	77.0
	5(B)	0	4,721	0	16	\$65	\$0	\$289	\$5,076	-0.6	N/A
	6	3	14,412	0	49	\$197	\$64	\$0	\$4,821	0.7	17.5
	7	0	0	11	11	\$32	\$0	\$320	\$5,620	-0.5	N/A
	8	0	0	272	272	\$794	\$0	\$1,632	\$28,699	-0.2	N/A
	9	0	0	14,980	14,980	\$43,742	\$0	\$3,000	\$105,344	2.4	7.6
	10	0	0	1,537	1,537	\$4,488	\$0	\$1,799	\$24,869	1.7	8.9
	12	0	0	196	196	\$572	\$0	\$0	\$31,635	0.3	52.6
5900	1	0	519,104	0	1,772	\$7,112	\$0	\$319	\$5,620	11.1	0.8
	2	9	539,430	0	1,841	\$7,390	\$193	\$1,188	\$20,887	2.8	3.1
	3	154	718,000	0	2,451	\$9,837	\$3,302	\$3,000	\$49,465	0.6	14.8
	4	1,890	0	0	0	\$0	\$40,529	\$0	\$504,000	0.9	12.4
	5(A)	0	15,915	0	54	\$218	\$0	\$0	\$8,154	0.3	35.6
	5(B)	0	21,175	0	72	\$290	\$0	\$425	\$7,469	-0.2	N/A

TABLE ES-3
ECONOMIC SUMMARY OF ECOs LISTED BY CENTRAL PLANT

CENTRAL PLANT	ECO NO.	ANNUAL DEMAND SAVINGS (kW)	ANNUAL ELEC. SAVINGS (kWh)	ANNUAL NAT.GAS SAVINGS (MMBtu)	TOTAL ENERGY SAVINGS (MMBtu)	ANNUAL ENERGY SAVINGS (\$)	ANNUAL DEMAND CREDIT (\$)	ANNUAL MAINT. COST (\$)	CONST. COST (\$)	SIR	SIMPLE PAYBACK (YRS)
5900	6	28	42,400	0	145	\$581	\$600	\$0	\$58,343	0.2	47.0
(Continued)	7	0	0	161	161	\$470	\$0	\$306	\$5,377	0.6	31.2
	8	0	0	6,157	6,157	\$17,978	\$0	\$2,745	\$48,257	4.3	3.0
	9	0	0	7,241	7,241	\$21,144	\$0	\$1,792	\$12,685	20.5	0.6
	10	0	0	3,182	3,182	\$9,291	\$0	\$4,247	\$44,010	1.9	8.3
	12	0	0	6,389	6,389	\$18,656	\$0	\$0	\$140,396	2.5	7.2
	13	0	203,000	0	693	\$2,781	\$0	\$2,507	\$157,969	0.0	547.0
6003	1	0	215,000	0	734	\$2,946	\$0	\$320	\$5,620	5.3	1.7
	4	544	0	0	0	\$0	\$11,666	\$0	\$204,000	0.7	17.5
	5(A)	0	25,818	0	88	\$354	\$0	\$0	\$11,002	0.4	29.6
	5(B)	0	31,025	0	106	\$425	\$0	\$570	\$10,021	-0.2	N/A
	6	12	25,861	0	88	\$354	\$257	\$0	\$23,185	0.3	36.1
	7	0	0	67	67	\$196	\$0	\$255	\$4,482	0.0	N/A
	10	0	0	450	450	\$1,314	\$0	\$1,187	\$20,083	0.3	150.4
	15	417	977,000	(49,603)	(46,268)	(\$131,456)	\$8,942	\$3,000	NA		

TABLE ES-4
ECOs EVALUATED LISTED BY CENTRAL PLANT

ECO NO.	CENTRAL PLANT								
	730	914	2812	3442	4701	5676	5678	5900	6003
1	X			X	X			X	X
2	X			X	X			X	
3	X	X	X		X	X		X	
4	X	X	X	X	X	X	X	X	X
5(A)	X		X			X	X	X	X
5(B)	X	X	X	X	X	X	X	X	X
6	X	X	X	X	X	X	X	X	X
7	X	X	X		X	X	X	X	X
8		X	X				X	X	
9		X	X			X	X	X	
10	X				X	X	X	X	X
11									
12					X	X	X	X	
13								X	
14	X				X				
15									X
16			X						
17	X		X						

TABLE ES-5
ECOs CONSIDERED NOT FEASIBLE

CENTRAL PLANT	ECO NO.	COMMENTS
730	8	No opportunity for boiler optimization.
	9	No opportunity for additional savings for boiler renovation.
	11	No high efficiency burners small enough for these boilers.
	12	No opportunity for additional savings with stack economizer.
914	1	No opportunity for savings by operating less equipment. There is only one chiller.
	2	No opportunity for savings by optimizing chillers. There is only one chiller.
	5(A)	The cooling tower already has two-speed tower fans.
	10	These burners are non-modulating type burners. Oxygen trim will not work.
	11	No high efficiency burners small enough for these boilers.
	12	No opportunity for additional savings with stack economizer.
2812	1	No opportunity for savings by operating less equipment. There is only one chiller.
	2	No opportunity for savings by optimizing chillers. There is only one chiller.
	10	These burners are non-modulating type burners. Oxygen trim will not work.
	11	No high efficiency burners small enough for these boilers.
	12	No opportunity for additional savings with stack economizer.
3442	3	No opportunity for more efficient chillers.
	5(A)	This cooling tower has four cells. It is not feasible to add two-speed control.

TABLE ES-5
ECOs CONSIDERED NOT FEASIBLE

CENTRAL PLANT	ECO NO.	COMMENTS
4701	5(A)	This cooling tower has four cells. It is not feasible to add two-speed control.
	8	No opportunity for boiler optimization.
	11	No high efficiency burners small enough for these boilers.
5676	1	No opportunity for savings by operating less equipment. There is only one chiller.
	2	No opportunity for savings by optimizing chillers. There is only one chiller.
	11	No high efficiency burners small enough for these boilers.
5678	1	No opportunity for savings by operating less equipment. There is only one chiller.
	2	No opportunity for savings by optimizing chillers. There is only one chiller.
	3	No opportunity for more efficient chillers.
	11	No high efficiency burners small enough for these boilers.
5900	11	No high efficiency burners small enough for these boilers.
6003	2	No opportunity for chiller optimization. Both chillers are the same size and efficiency.
	9	No opportunity for additional savings.
	11	No high efficiency burners small enough for these boilers.
	12	No opportunity for additional savings with stack economizer.

PROJECTS DEVELOPED

At the Interim Submittal review conference with Fort Sill DEH, the individual ECOs which were determined to be economically viable were reviewed. The individual ECOs were either grouped into projects or eliminated because of functional decision making. Five projects were developed from the individual ECOs. These projects were evaluated to determine if they were economically feasible for funding under the Energy Conservation Investment Program (ECIP). The five projects developed for further analysis included:

- Project 1 - Control project for Central Plants 730, 5900, and 6003: Install microprocessor-based instrumentation and controls to remotely monitor and control mechanical equipment in central plants. The control system monitors central plant loads and selects appropriate equipment to match the equipment capacity with the load, thereby saving energy.
- Project 2 - Central heating plant project and control project for Buildings 5676 and 5678: Expand existing central plant to provide heating. Boilers and pumps are replaced to improve efficiency, thereby saving energy.
- Project 3 - Replacement of boilers 1 and 2 in Central Plants 2812 and 5900: Replace boilers 1 and 2 in Central Plants 2812 and 5900 to improve boiler efficiency, thereby saving energy.
- Project 4 - Replacement of chiller in Central Plant 2812 with a higher efficiency chiller: Replace chiller in Central Plant 2812 with a high efficiency chiller matched to the central plant loads, thereby saving energy.
- Project 5 - Comparison of local hot water boiler in each barracks versus central heating plant project, 3400 Area: Compare replacement of steam boilers with high efficiency modular hot water boilers in barracks versus constructing a central heating plant to provide hot water.

Table ES-6 on page ES-16 summarizes the economics of the projects listed above. Table ES-7 on page ES-16 demonstrates annual potential energy conserved and cost savings. The evaluation results indicate:

- Projects 1, 2, and 4 would not qualify for ECIP funding.
- Project 3 would qualify for ECIP funding.
- The life cycle cost of individual hot water boilers in each barracks is less than a new central plant.

TABLE ES-6
ECONOMIC SUMMARY OF PROJECTS DEVELOPED

PROJECT NUMBER	ECONOMIC LIFE (YRS)	CONSTRUCTION COST (\$)	ANNUAL ENERGY SAVINGS			ANNUAL DOLLAR SAVINGS			SIR	SIMPLE PAYBACK (YRS)
			PEAK DEMAND (kW)	ELECTRICAL (kWh)	NAT. GAS (MMBtu)	DEMAND (\$)	ELECTRICAL (\$)	NAT. GAS (\$)		
1	15	608,539	164	1,507,208	7,682	3,517	20,649	22,431	0.50	32.8
2	25	309,222	0	0	2,956	0	0	8,632	0.49	58.0
3	25	493,543	14	122,000	29,160	300	1,671	85,819	3.84	6.2
4	25	208,111	23	78,000	0	493	1,069	0	0.00	N/A
5	25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

The results of Life Cycle Cost for both case studies for Project 5 indicate:

- \$4,606,271 for replacement of modular hot water boilers in each barracks.
- \$5,864,140 for construction of new central heating plant for all 3400 Area barracks.

416 MMBTU
→ 29,160
29,160
416

300
1,671
85,819
87,790

TABLE ES-7
ANNUAL POTENTIAL ENERGY CONSERVED AND COST SAVINGS

ITEM	PEAK ELECTRICAL DEMAND	ELECTRICAL ENERGY	NATURAL GAS
CURRENT POSTWIDE CONSUMPTION	287,633 kW	151,843,500 kWh	1,026,161 MMBtu
CONSUMPTION WITH PROJECT IMPLEMENTED (PROJECT 3)	287,619 kW	151,721,500 kWh	995,942 MMBtu
PERCENT SAVING	0.005 %	0.08 %	3.0 %
DOLLAR SAVING	\$300	\$1,670	\$88,240

PRESENT ENERGY CONSUMPTION

Historical energy usage data at Fort Sill was evaluated to compare savings figures with actual consumption.

Electrical energy consumption, demand, and costs for FY90 are tabulated in Table ES-8 on page ES-18. The monthly electrical consumption for FY90 varies from a minimum of 9,049,600 kWh in November, to a maximum of 18,376,344 kWh in August. The monthly electrical consumption is illustrated graphically in Figure ES-1 below.

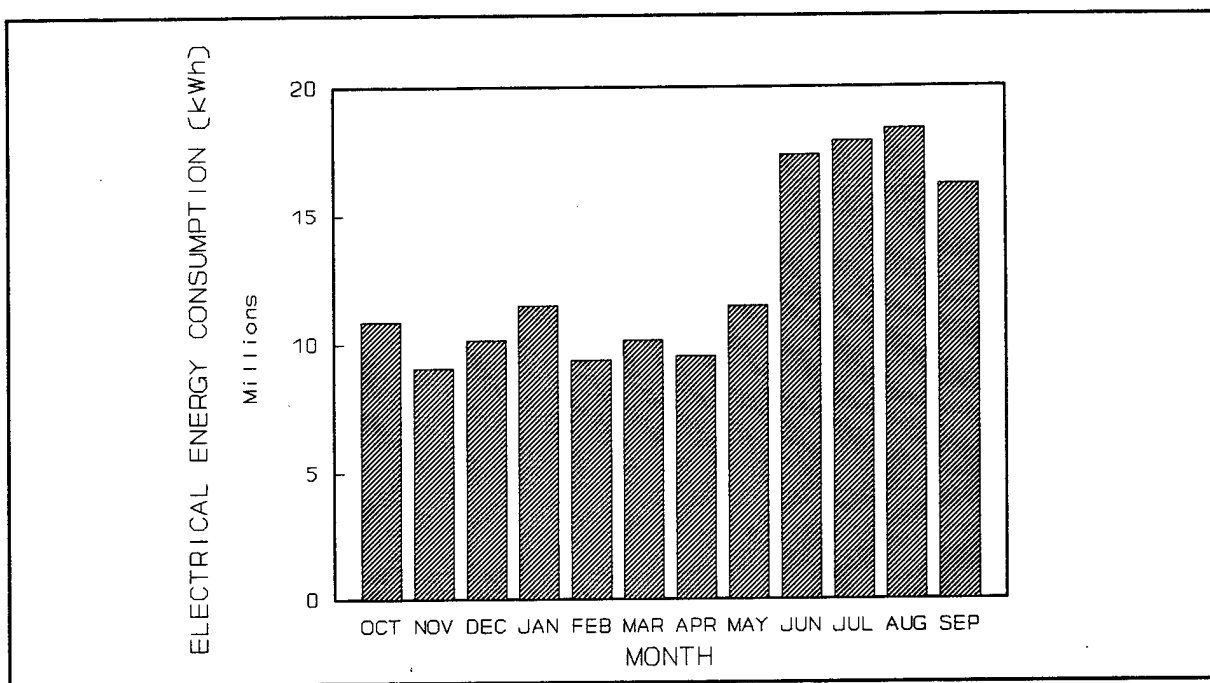


FIGURE ES-1, MONTHLY ELECTRICAL CONSUMPTION

**TABLE ES-8
ELECTRICAL USAGE AND BILLING**

SERVICE MONTHS FY 90	ELECTRICAL ENERGY TOTAL (kWh)	FEDERAL GENERATED ENERGY (kWh)	THERMAL ENERGY (kWh)	ACTUAL DEMAND (kW)	FIRM CAPACITY DEMAND (kW)	THERMAL DEMAND (kW)	FEDERAL GENERATED ENERGY COST (\$)	THERMAL ENERGY COST (\$)	FEDERAL GENERATED DEMAND COST (\$)	THERMAL DEMAND COST (\$)	TOTAL ELECTRICAL COST [1] (\$)
OCT	10,859,520	9,758,900	1,100,620	20,815.2	36,700	35,641	\$39,035.60	\$26,965.19	\$108,632	\$63,690.82	\$28,322.61
NOV	9,049,600	4,630,583	4,419,017	17,530.8	36,700	35,641	\$18,522.33	\$105,406.81	\$108,632	\$63,690.82	\$296,251.96
DEC	10,146,864	0	10,146,864	18,933.6	36,700	35,641	\$0.00	\$241,251.84	\$108,632	\$63,690.82	\$413,574.66
JAN	11,481,680	7,041,950	4,439,730	18,236.4	36,700	35,641	\$28,167.80	\$94,339.83	\$108,632	\$63,690.82	\$294,830.45
FEB	9,377,648	9,377,648	0	17,858.4	36,700	35,641	\$37,510.59	\$0.00	\$108,632	\$63,690.82	\$209,833.41
MAR	10,158,176	10,158,176	0	17,808.0	36,700	35,641	\$40,632.70	\$0.00	\$108,632	\$63,690.82	\$212,955.52
APR	9,527,263	9,527,263	0	17,740.8	36,700	35,641	\$38,109.05	\$0.00	\$108,632	\$63,690.82	\$210,431.87
MAY	11,453,400	11,453,400	0	25,880.4	36,700	35,641	\$45,813.60	\$0.00	\$108,632	\$63,690.82	\$218,136.42
JUN	17,358,264	17,358,264	0	33,843.6	36,700	35,641	\$69,433.06	\$0.00	\$108,632	\$63,690.82	\$241,755.88
JUL	17,884,272	17,884,272	0	33,339.6	36,700	35,641	\$71,537.09	\$0.00	\$108,632	\$63,690.82	\$243,859.91
AUG	18,376,344	10,444,935	7,931,409	33,705.0	36,700	35,372	\$41,775.74	\$199,704.95	\$108,632	\$63,120.41	\$413,237.10
SEP	16,170,504	5,437,224	10,733,280	31,941.0	36,700	33,844	\$21,748.90	\$240,071.27	\$108,632	\$60,478.51	\$430,930.68
TOTAL	151,843,535	113,072,615	38,770,920	287,633			\$452,290	\$907,740	\$1,303,584	\$760,507	\$3,424,121

Natural gas consumption for FY89 is tabulated in Table ES-9 below. The monthly natural gas consumption for FY89 varies from a minimum of 21,739 MMBtu in August to a maximum of 222,094 MMBtu in February. The monthly natural gas consumption is illustrated graphically by Figure ES-2 on page 21.

TABLE ES-9
NATURAL GAS CONSUMPTION - FY89

Month	MMBtu Consumption
October	38,562
November	108,070
December	163,565
January	173,196
February	222,094
March	135,771
April	50,266
May	29,267
June	26,329
July	26,000
August	21,739
September	31,302
Total	1,026,161

Table ES-10 on page ES-20 lists the estimated annual baseline energy consumption and demand of the nine central plants evaluated in this study.

TABLE ES-10
ANNUAL ENERGY CONSUMPTION OF CENTRAL PLANTS

CENTRAL PLANT	PEAK ELECTRICAL DEMAND (kW)	ANNUAL ELECTRICAL CONSUMPTION (kWh/yr)	ANNUAL NAT. GAS CONSUMPTION (MMBtu/yr)	TOTAL ENERGY CONSUMPTION (MMBtu/yr)
730*	732	1,175,000	27,469	31,479
914	286	563,000	13,852	15,774
2812*	93	386,000	21,453	22,770
3442	590	1,340,000	0	4,573
4701	396	306,000	9,596	10,640
5676*	165	200,000	4,780	5,463
5678*	146	190,000	5,639	6,287
5900*	1,781	4,632,678	79,219	95,030
6003*	563	1,861,000	42,402	48,754
TOTAL		10,653,678	204,410	240,770

* Energy consumption has been revised for Prefinal Submittal; assumed no EMCS.

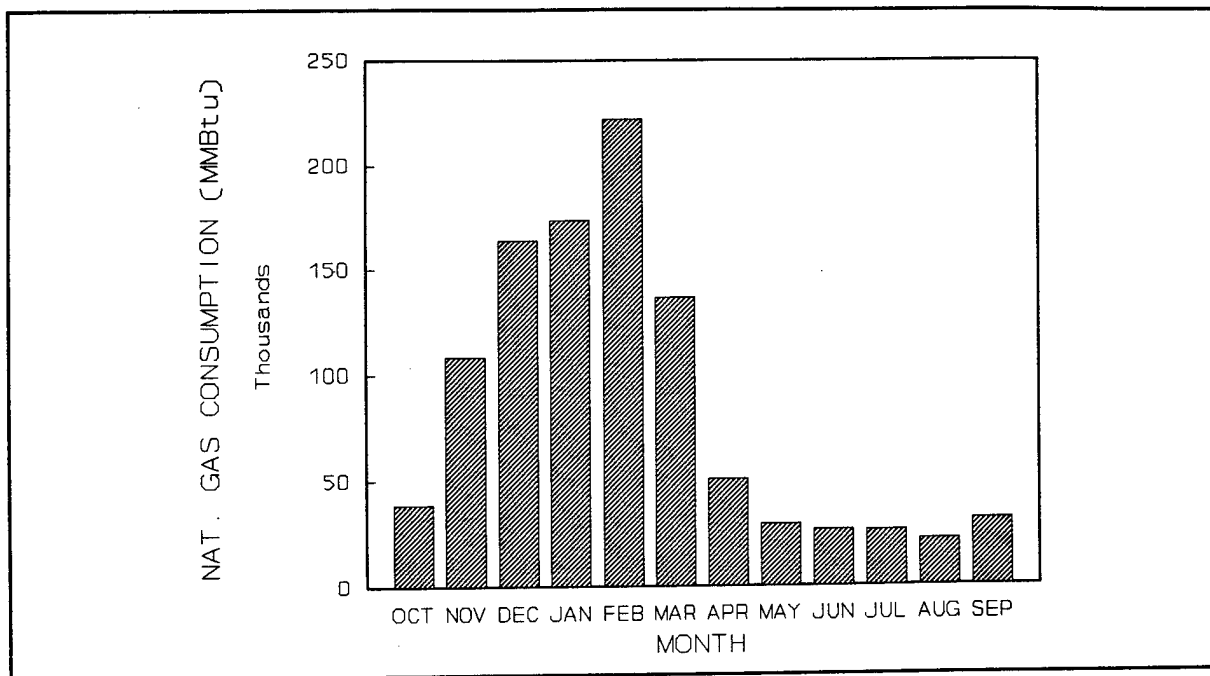


FIGURE ES-2, MONTHLY NATURAL GAS CONSUMPTION

CENTRAL PLANT SPECIAL CONSIDERATIONS

Several central plants were evaluated to determine if excess capacity exists which can be used for heating and cooling requirements in other buildings. The findings of this review are noted:

- Central Plant 730 has 371 tons of excess cooling capacity.
- Central Plant 1653 has 1.47 MMBtuh of excess heating capacity.
- Central Plant 3442 has 171 tons of excess cooling capacity.
- Central Plant 6003 has 19.03 MMBtuh of excess heating capacity and 535 tons of excess cooling capacity.

Central plants were reviewed as to the technical merits of consolidating central plants. The findings of this review included:

- Central Plants 5676 and 5678: The central plants in these two buildings are in close proximity, allowing a relatively easy installation.

- Plant 3442 addition: A project to add a central high temperature hot water (HTHW) boiler plant to Building 3442 was previously evaluated under a fort-wide energy study. This project is currently programmed for construction with a barracks upgrade project.
- Central Plant 914: The central heating plants in Buildings 900, 912, 913, and 914 are in close proximity, allowing a relatively easy installation (the chiller plants are already connected); however, unless there is a need to replace the existing equipment because of age and condition, it would be difficult to economically justify consolidation of the heating plants.
- Area 800, central energy plant: A central plant for the 800 area to displace existing plants in Buildings 445, 462, 730, 913, 1603, and 1653 was evaluated under a fort-wide energy study. The economics of this project were low, and Fort Sill has not programmed this project.

CENTRAL PLANT OPERATIONAL RECOMMENDATIONS

The operational items noted which will provide Fort Sill with energy savings at low cost or no cost include:

- Maintain and review log data on a periodic basis for all chillers and boilers to track potential changes in operating conditions which may indicate problems and inefficient operation.
- Use existing microprocessor-based controls on chiller plants as effectively as possible. If Fort Sill has insufficient documentation and training, efforts should be made to obtain more from the manufacturer.
- For minimum chiller energy usage, the condenser water temperature setpoint should be as low as can be safely used by the refrigeration system, or as low as can be provided under the outdoor air conditions. This applies to all central chiller plants.
- The lower basin of the cooling tower above the two-cell partition should be filled to eliminate cross-flow between cells. If only one fan is running, when the water level is below the partition, air is pulled through the second fan opening, and not through the cooling tower media. As a result, one fan runs longer because the air is not flowing across the condenser water. This applies to Central Plants 730, 914, and 3442.
- Various operating conditions of hot water temperatures and hot water pumping from Central Plant 730 should be tested. To reduce distribution losses, hot water supply temperatures should be maintained at a minimum. To lower pumping requirements, the minimum number of water pumps should be run to meet the heating load. This applies to Central Plants 730, 914, 5676, 5678, and 5900.

- To maintain the longer boiler life associated with lower boiler temperatures and pressures, operators should also try lowering the boiler steam pressure from 10 psig to less (2 psig to 5 psig). This applies to Central Plants 730, 914, and 2812.
- Operate the minimum number of chillers, boilers, and pumps required to meet the cooling and heating loads. In many cases, extra chillers, boilers, and pumps are being operated unnecessarily, wasting energy. The following specific operating procedures for each central plant are recommended as a guide for the operator.

INDIVIDUAL CENTRAL PLANT DESCRIPTIONS AND OPERATIONAL RECOMMENDATIONS

Central Plant 730

Chillers:

Central Plant 730 has two chillers, one 300 tons and one 800 tons, which are operational. The chillers in Central Plant 730 could be run more efficiently if additional attention is directed at operating those chillers and pumps most suited to fit the estimated load. No instrumentation is present to inform operators of the size of the load currently on the plant.

Boilers:

Three of the four boilers in Central Plant 730 operate during the winter to meet heating and DHW loads. No master boiler control is present to control staging of the boilers. To minimize operating time when boilers are in a low fire or standby mode, individual boiler controls should be set to stage the three boilers in a lead-lag configuration. Fort Sill will save energy by minimizing standby losses if the boilers are operated more efficiently to meet the load.

Central Plant 914

Chillers:

Central Plant 914 has one 400 ton chiller which, although new, is not operating at rated capacity or specified efficiency. (See survey information discussed in Section 2.2.2 on page 2-11 of this submittal.) The measured efficiency was 1.23 kW per ton, versus the design rating of 0.65 kW per ton to 0.7 kW per ton. The pressure drop across the evaporator was much higher than the design; EMC noted a drop of 23 foot head of water, compared to a maximum design of 10 foot head of water. This indicates a potential problem with clogged tubes (fouling). The same problem was experienced with the pressure drop across the condenser; however, this problem is not as severe. For the condenser, EMC measured the pressure drop at 13.8 foot head of water, compared to a design pressure drop of 10 foot head of water. Cleaning the tubes, as well as diagnosing and

solving this problem will assure there is adequate capacity for the cooling load, and will also save energy because of higher efficiencies.

Although a microprocessor-based control system is available for this central plant, the chiller controls were set on manual when surveyed.

Recommended operation of the chiller plant is as follows:

- Maximum chilled water return temperature, 58°F.
- Minimum chilled water supply setpoint, 45°F.
- To maintain the return temperature at 58°F, the microprocessor-based control system should be programmed to reset the chilled water supply temperature setpoint.

Boilers:

Central Plant 914 has four boilers, three of which operate during the winter to meet the heating load and one which operates year-round to meet DHW loads. No master boiler control is present to control staging of the boilers. To minimize operating time when boilers are in a low fire or standby mode, individual boiler controls should be set to stage the three boilers in a lead-lag configuration. Fort Sill will save energy by minimizing standby losses if the boilers are operated more efficiently to meet the load.

Boilers 3 and 4 in Central Plant 914 produce soot during firing, and soot is removed on a regular basis. This is apparently caused by the unsatisfactory arrangement of individual outlets into the common breaching. Another possible cause is the forced draft burner of the boiler nearest the stack, which may create a positive pressure in the breaching, thus eliminating the stack draft from the three atmospheric burners in this central plant. In order to avoid future problems with soot buildup, the root of the problem must be corrected, rather than continually removing soot.

Central Plant 2812

Chillers:

Recommended operation of the chiller plant is as follows:

- Maximum chilled water return temperature, 61°F.
- Minimum chilled water supply setpoint, 40°F.
- The chilled water supply temperature setpoint should be reset manually to maintain the return temperature at 61°F.

Boilers:

Central Plant 2812 has three boilers, two of which operate during the winter to meet the heating and DHW loads, and one which operates year-round to provide steam for the mess hall, Building 2811. No master boiler control is present to control staging of the boilers.

Central Plant 3442

Chillers:

Central Plant 3442 has two 600 ton chillers. Although a microprocessor-based control system is available for this plant, the chiller controls were set on manual when surveyed. The telephone line connecting the central plant microprocessor-based controls with the DEH operator console had been removed.

Fort Sill would benefit if communication command were to reinstall a telephone line to provide remote monitoring of the central plant. In addition, the microprocessor-based control system should be tested and made operational to optimize chiller usage. The chillers in Central Plant 3442 will be run more efficiently if additional attention is directed at those chillers and pumps most suited to fit the estimated load. No instrumentation is present to inform operators of the size of the load currently on the plant.

Central Plant 4701

Chillers:

Central Plant 4701, which serves the hospital, has two 275 ton chillers. One of the chillers operates at very poor efficiency (1.31 kW per ton), while the other chiller surges. Chiller 1 requires constant refrigeration charging. Diagnosing and solving the problems will assure adequate capacity for the cooling load and will also save energy by increasing efficiency.

Because of the critical requirements of the hospital, the operators should continue to operate the chillers as needed to maintain environmental conditions. Based on the efficiency of the two chillers, it is recommended the operators use chiller 2 first. When the hospital operations are moved to the new facility and Building 4700 no longer has critical requirements, the operators should attempt to reset chilled water temperatures to save energy.

Based on the original design drawings for the hospital, the chiller plant was set to operate as follows:

- Maximum chilled water return temperature, 53°F.
- Chilled water supply setpoint, 43°F.

- One chilled water pump and one condenser pump have adequate flow for both chillers.

Boilers:

Central Plant 4701 has three boilers, two of which operate during the winter to meet the heating and DHW loads. No master boiler control is present to control staging of the boilers. To minimize operating time when boilers are in a low fire or standby mode, individual boiler controls should be set to stage the three boilers in a lead-lag configuration. Fort Sill will save energy by minimizing standby losses if the boilers are operated more efficiently to meet the load.

When Building 4700 is converted to an administrative building and there is no need for high pressure steam, the central plant will not require an operator in attendance. Additionally, it is anticipated the steam pressure can be reduced from 100 psig to less than 15 psig, while continuing to maintain satisfactory capacity with the associated longer life of a boiler operating at lower pressures and temperatures.

Central Plant 5676

Chillers:

Central Plant 5676 has one 170 ton chiller which operates at 1.53 kW per ton, very poor efficiency when compared to the chiller in Central Plant 5678, which operates at 0.73 kW per ton. Diagnosing and solving the problem with this chiller will assure adequate capacity for the cooling load, and will also save energy because of higher efficiency.

Recommended operation of the chiller plant is as follows:

- Maximum chilled water return temperature, 52°F.
- Minimum chilled water supply (setpoint) temperature, 44°F.
- Chilled water supply temperature setpoint should be reset manually to maintain the return temperature at 52°F.

Additional operational action items:

- The flow ports on the upper basin of the cooling tower are clogged with dirt and debris, causing the condenser water to overflow. These ports should be cleaned to assure proper flow across the cooling tower media.

Boilers:

Both boilers in Central Plant 5676 operate during the winter to meet the heating load. No master boiler control is present to control staging of the boilers. To minimize operating time when boilers are in a low fire or standby mode, individual boiler controls should be set to stage the boilers in a lead-lag configuration. Fort Sill will save energy by minimizing standby losses if the boilers are operated more efficiently to meet the load.

Central Plant 5678

Chillers:

The 190 ton chiller in Central Plant 5678 surged when it was tested above 4° delta T. Diagnosing and solving the problem with this chiller will assure adequate capacity for the cooling load, and also save energy because of higher efficiencies.

Recommended operation of the chiller plant is as follows:

- Maximum chilled water return temperature, 53°F.
- Minimum chilled water supply setpoint, 45°F.
- Chilled water supply temperature setpoint should be reset manually to maintain the return temperature at 53°F.

Boilers

The two boilers in Central Plant 5678 operate during the winter to meet heating and DHW loads. No master boiler control is present to control staging of the boilers. To minimize operating time when boilers are in a low fire or standby mode, individual boiler controls should be set to stage the boilers in a lead-lag configuration. Fort Sill will save energy by minimizing standby losses if the boilers are operated more efficiently to meet the load.

Central Plant 5900

Chillers:

Central Plant 5900 has five chillers, including four 400 ton units and one 450 ton unit. Efficiencies range from 0.83 kW per ton to 0.94 kW per ton. Only one mechanical problem was noted with the chillers: the cooling tower on chiller 1 seems to be undersized and not able to provide adequate condenser cooling capacity.

The chillers in Central Plant 5900 will be run more efficiently if additional attention is directed at operating the chillers and pumps most suited to fit the estimated load. No instrumentation is present to inform operators of the size of the load currently on the central plant.

Additional operational action items:

- No extra chilled water pumps should be run without an associated chiller.
- The differential pressure controller and control valves on the discharge of the plant should be checked to determine the current operating condition of each.

Boilers:

The six HTHW boilers in Central Plant 5900 operate during the winter to meet the heating and DHW loads. No master boiler control is present to control staging of the boilers. When the last boiler was added to the central plant, the main HTHW flow meter in the central plant was not changed to measure the new maximum flow capacity from the central plant. As a result, operators cannot determine the heating capacity of the central plant. The main flow meter should be replaced and calibrated to match the maximum load flow condition from the central plant; the chart recorders should be adjusted to register the flows. With knowledge of the heating loads on the central plant, the boilers can be run more efficiently to meet the loads, thus minimizing standby losses and saving energy.

Central Plant 6003

Chillers:

Central Plant 6003 has two 450 ton chillers which are operational and one 400 ton chiller which is not operational. The chillers in Central Plant 6003 will be run more efficiently if additional attention is directed at operating the chillers and pumps most suited to fit the estimated load. Although a sequence panel exists to operate the two chillers in a lead-lag manner based on current limits, the sequence panel was not used. Chiller 2 is experiencing mechanical problems. Cleaning the tubes and diagnosing and solving the mechanical problems will assure adequate capacity for the cooling load and will save energy by increasing efficiency.

Boilers:

Central Plant 6003 has three boilers, two of which operate during the winter to meet the heating and DHW needs. No master boiler control is present to control staging of the boilers. To minimize operating time when boilers are in a low fire or standby mode, individual boiler controls should be set to stage the three boilers in a lead-lag configuration. Fort Sill will save energy by minimizing standby losses if the boilers are operated more efficiently to meet the load.

REFRIGERANTS

Under the Clean Air Act of 1990, the United States Congress adopted an accelerated phase-out schedule, cutting chlorofluorocarbon (CFC) production to 50% of the 1986 levels by 1995 and to 15% by 1997. This country's CFC production will end by the year 2000. Because most of the chillers at Fort Sill now use CFC-11 or CFC-12, the required changes in CFC production will have a major impact.

A number of economic factors must be considered in determining whether to purchase new equipment or to convert existing chillers. These factors include:

- Estimated equipment life
- Equipment current performance
- Operating requirements
- Cost of new equipment
- Cost of equipment room modifications
- Maintenance and refrigerant costs
- Utility costs.

The EPA forecasts the cost of CFC-11, which is currently \$3.50 to \$4 per pound, will rise to \$12 per pound by 1999. Thus, a 1,000-pound charge costing around \$4,000 today would be \$12,000 in 1999. The cost today for HCFC-123 is about double the cost of CFC-11; HCFC-123, however, is trending downward, while CFC-11 is trending upward. Du Pont predicts a pricing crossover will occur sometime in 1992 or 1993.

If a system now operating on CFC has marginal capacity, converting to a new refrigerant may leave it short of capacity or with poor performance. The manufacturers are currently testing and developing performance charts for HCFC conversions. When this information is complete, the government should make a comprehensive evaluation to determine how the new refrigerant will affect capacity and efficiency and what modifications are needed to achieve optimum performance.

OTHER RECOMMENDATIONS

- In the future, Fort Sill should review third-party financing (TPF) as a possible alternative for central plant renovations, additions, and operations.
- In the future, Fort Sill should develop operational procedures for each central plant to optimize plant operations and conserve energy. Each central plant operator should be given a bound copy of the operational procedures, engineering look-up tables, and test instrumentation, along with formal training in the importance of central plant maintenance and operations on energy conservation and utility cost savings.
- In the future, Fort Sill should train a single specialized maintenance crew to test and adjust boilers with a flue gas analyzer, rather than having these procedures performed by each central plant operator.